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Before the public can freely and fairly contribute to the environmental decision process, education on the importance of ecological and genetic diversity is needed. Education will assist the public in assigning both cost and quality of live values to environmental effects as part of the process of assessing the adversity of an effect. Only when the value of an ecological good or service is understood can we determine whether or not to accept the impact or take action to prevent the adverse effect. The decision to prevent or limit adverse effects ultimately leads to regulatory policy.

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Definition of Adverse Effects for the Purpose of Establishing Secondary National Ambient Air Quality Standards

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CLEAN AIR ACT AND AMBIENT AIR QUALITY STANDARDS

The Clean Air Act requires the Administrator of the U.S. Environmental Protection Agency (EPA) to establish national ambient air quality standards [1]. The Administrator is responsible for the attainment and maintenance of these standards in order to protect the public health and welfare from any known or anticipated adverse effects associated with the presence of criteria air pollutants (e.g., ozone, sulfur dioxide) in the ambient air. Secondary national ambient air quality standards are established to prevent adverse welfare effects. These effects include, but are not limited to, effects on soils, water, vegetation, animals, visibility, weather, climate, damage to and deterioration of property, as well as effects on economic values and personal comfort/well-being [2].

The scientific basis for ambient air quality standards is contained in air quality criteria documents [3,4]. These documents include the scientific information on "all identifiable effects" ascribed to the pollutant and the pollutant concentrations and exposure durations associated with the effects. Concern is frequently expressed over the lack of differentiation among the various types of effects and their relative importance, i.e, which effects are genuinely adverse and which are inconsequential and should carry little or no weight in standard setting [5,6]. For example, in the recent Draft Staff Paper [7], prepared for the on-going review of the ambient air quality standards for ozone, a distinction was made between the relative importance of foliar injury to vegetation and reduced crop yield. The conclusion reached in the document was that, "...greater emphasis will be placed on damage or yield loss than on injury".

DEFINITION OF "ADVERSE" - WHO MAKES THE DETERMINATION

Dictionaries define adverse as, "opposed to one's interest or welfare; harmful; detrimental". The context within which an effect is evaluated is important [8]. The effect must be evaluated from both its societal impact as well as its ecological impact. From either perspective, the measured effect must be something of value. At issue is the importance of the biological data, i.e., its meaning to public welfare, not its scientific validity or our technical ability to measure the effect [5]. Several general criteria [8] have been suggested to determine the willingness of the public to accept the adversity of a biological effect: (1) the magnitude of the impact; (2) the spatial extent of the impact; (3) the duration of the impact; and (4) the likelihood of the occurrence of the impact.

The definition of "adverse" ultimately involves an interplay among scientists and society. In this interplay, the role of the scientist is first to identify, measure or describe the effect,

and second, to help explain to the public the significance of the effect in biological or ecological terms. In the context of the Clean Air Act, society is represented by the Administrator who establishes ambient air quality standards to protect public welfare from adverse effects. In this role, the Administrator determines if he is willing to either accept the impact/consequence of an biologically adverse effect or to take action (i.e., expend money and resources) to reduce or limit the consequences of the adverse effect. This interplay requires that scientists explain the impacts in ways that can be understood. Also, the public must be sufficiently educated to understand the effects and determine whether or not it is willing to accept the consequences. Scientists can establish if air pollutants are reducing crop yield or impairing an ecological function. But the Administrator must determine if he wishes to prevent or only to reduce the extent/magnitude of crop losses or ecological impairment. For example, if the Administrator decides only to reduce crop losses, instead of preventing them, then he must determine the magnitude of crop loss (i.e., 10% or 1%) that he is willing to accept. The social willingness to accept a consequence can be expressed economically (i.e., willingness to pay) as well as politically. The scientist can help the decision-maker (the Administrator) by describing the ecological importance of the effect on the ecological resources under consideration [8].

ADVERSE EFFECTS ON VEGETATION

The various effects of air pollutants are not equally important. An example of the differential valuation of effects is the common usage in the vegetation effects literature of the terms, "injury" and "damage" [9]. "Injury" encompasses all measurable plant reactions, such as reversible changes in metabolism, reduced photosynthesis, leaf necrosis, leaf drop, altered quality or reduced growth that do not influence agronomic yield or reproduction. In contrast, "damage" includes all effects that reduce the intended human use or value of the plant or ecosystem. From this perspective "damage" is equivalent to an "adverse" effect, and can be segregated into four major categories: (1) economic production; (2) ecological structure and function; (3) genetic resources; and (4) cultural values. Examples of the various types of adverse effects will be drawn from the four categories.

1. Economic production

Economic damage to agriculture and forestry results directly from impacts on plants and indirectly through changes in farming, management and/or cultural practices. Direct economic damage includes effects on growth, yield and quality, if these reductions impair the intended use. Products used as food,

fodder, or ornamental plants may show both quantitative and qualitative losses ranging from changes in the nutritional metabolites that influence product quality to changes in appearance, i.e., marketability. Numerous studies have documented the impact of air pollutants on plant growth, yield and quality [2,3,4]. Ozone effects on crop yield cause significant economic losses. Using ozone exposure-response data for eight major agricultural crops, economic models estimate the annual economic loss from ozone at approximately 2-3 billion dollars [10].

In addition to the direct impact of air pollutants, losses also occur when species adapted for cultivation in specific locations can no longer be grown because they are sensitive to pollutants. The need to cultivate relatively pollutant-resistant species may cause changes in management or cultural practices that result in disadvantages for crop production [9]. Little information exists on the consequences of air pollution on altered resistance to biotic and abiotic stresses. However, ozone is known to increase the susceptibility of crops to pests/pathogens [9]. Thus additional pesticide applications are needed to reduce the pest/pathogen population. These applications increase the economic cost of production, as well as the ecological costs due to potential contamination of the food web from increased pesticide usage.

2. Ecological structure and function

Human welfare is inextricably linked to and dependent on the productivity and diversity of biological systems. The role of biological diversity in maintaining ecosystem "goods and services" is critical to the continuance of our survival. Despite their value and economic importance, the ecosystem goods and services are usually ignored or underestimated in cost-benefit analyses because these services are public goods, not priced in the marketplace [11,12].

Ecosystems are frequently characterized in terms of their structure and function [11]. Structure refers to the species, their biomass and their arrangement, i.e., the standing stock of the system. Ecosystem functions portray the interactions among the components of the ecosystem. These functions include: maintenance of hydrological cycles, climate regulation, erosion (wind and water) reduction, nutrient cycling , absorption and breakdown of pollutants, and maintenance of an environment favorable for human life [11].

The standing stocks of many ecosystems are harvested (e.g., timber, forest products, fish) and provide economic benefits. Air pollutants can adversely affect the structural components (standing stock, i.e., timber production) of ecosystems and can disrupt natural ecosystem functions [13,14,15,16]. For example, elevated levels of photochemical oxidants reduced the plant

species richness in coastal shrub communities in southern California [16]. Any simplification of an ecosystem that reduces the structural complexity also impacts wildlife, as the diversity of animal life is associated with the stratification and growth forms of plants. Air pollutant impacts on the ecosystem standing stock frequently impair economic value and could also be classified under economic production.

Air pollutants can impair ecosystem function, ultimately resulting in economic costs [11]. Reduction or elimination of plant cover by air pollution can indirectly accelerate soil erosion (i.e., reduce the soil binding function). The costs of this altered function include those associated with erosion and sedimentation causing continuing damage to certain sensitive organisms in the ecosystem and material structures such as dams [11]. Pollutants can also impair the sustainability of the system, i.e., the capacity of the system to maintain, over time, a level of plant or animal production that is considered optimal. If sustainability is impaired, additional inputs will be needed to compensate for the stress and additional costs will result.

3. Genetic Resources

Each species represents a genetic resource and a natural "chemical factory" that may be economically important [17]. Although there may be no known economic or other current human use for many unstudied species, past experience has shown that some of them will prove to be valuable [12]. For instance, the preservation of genetic diversity in crop plants and their relatives has proven valuable to maintain and ensure continued flexibility in crop breeding programs.

Airborne pollutants may alter the genetic diversity of populations [18]. Many declining species display low genetic diversity [19]. This loss of genetic diversity reduces a species' ability to adapt to changing environmental conditions and may result in possible extinction and loss to the gene pool. Gillespie and Guttman [20] state that pollutants may reduce genetic diversity of populations and thereby increase their susceptibility to the effects of further environmental changes. Their investigations of the impact of pollutants on the genetic diversity of certain fish species indicated that some genotypes were selectively eliminated within a single generation due to pollutant stress [20]. The impact of these losses on the gene pool, ecosystem function and cost to society is yet to be determined.

The mixed conifer forests of the San Bernardino and San Gabriel Mountains of southern California have been exposed to increased levels of ozone since the early 1950s [21]. Effects include increased mortality of ponderosa pine and other sensitive species [22]. In addition, increased mortality of pollution-

sensitive genotypes within species may lead to a reduction in genetic diversity. Changes in community structure, as ozone-sensitive species are replaced by more tolerant species, such as oaks and various shrubs, can lead to an increased frequency and severity of fires; these fires alter community structure further. The resulting, less diverse community may provide fewer recreational and economic "services".

4. Cultural values

Intangible environmental values derive from the belief that many features of ecosystems have a significant intrinsic value, apart from any economic value [12]. Natural ecosystems are rich in cultural (including religious, esthetic, and historic) importance for many people. In this context, it may be impossible and perhaps inappropriate to place an economic value on ecosystems. Through nature, humans find expressions of cultural and national identity. We may not consider the cultural values of our natural world as vital to human life, but certainly they affect our psychological and spiritual well-being. Indeed, it is the public response to visually decaying forests and vegetation that frequently results in an outcry to "do something".

ADVERSE EFFECTS - REGULATORY PROCESS

In the interactive process between science and society to determine the adversity of effects the premise has been argued that economic cost-benefit analyses provide a means to determine if regulatory or mitigative actions should be undertaken. Economic or monetary measures for defining adversity or the Administrator's willingness to accept an impact provide a common basis of measurement that is readily understood. Although such measures provide a common metric and a means to quantify some human and societal losses and gains, many effects on social structures and ecological resources are not adequately expressed in economic terms [8]. Quantitative measures of ecosystem change are difficult to obtain because effects are cumulative and may not appear for years. Thus ecosystems are difficult to evaluate from the biological as well as the economic perspective. For example, we do not know how to place an economic value on geochemical cycling and replenishment of nutrients in ecosystems, or dilution, dispersion and cleansing of pollutants from the atmosphere [24]. The economic values of ecological goods and services are frequently underestimated in cost-benefit analysis because of measurement and valuation difficulties [12]. Similarly, the practice of discounting economic costs and benefits favors short-term benefits with resultant long-term costs [12].

Executive Order 12291 [25] requires that all administrative decisions be based on adequate information concerning the need for and the consequences of the proposed governmental action.

Thus regulatory actions are not undertaken unless the potential benefits to society outweigh the potential costs to society. This order has frequently been interpreted to mean that economic cost is the measure of adversity. A corollary of this attitude is that an ecological effect is adverse only if it can be quantified and expressed in economic terms. The outcome of this interpretation is that mitigative or corrective actions need not be taken to protect ecological resources unless the costs of the action are off-set by sufficient monetary benefits. A major drawback to this interpretation is that economics and ecology are not sufficiently coordinated or advanced at present to allow a quantitative evaluation. Although the Executive Order requires full benefit-cost analyses to accompany regulations, many of the statutes (e.g., the Clean Air Act) that govern EPA limit its authority. By using the phrase "to the extent permitted by law" to qualify the directive, the Executive Order recognized that there may be instances where Congress has directed an agency to base its rule making on considerations other than cost-benefit analyses. Thus far EPA has not interpreted the Clean Air Act to allow a standard decision to be based directly on cost-benefit analyses.

It is necessary to view adverse effects in a broad context, i.e., the total benefits deriving from ecological systems. People need food, fiber, and fuel provided by biological systems; we should not lightly decide to impair the production of these commodities. Human welfare is inextricably linked to and dependent on the productivity and diversity of biological systems.

Before the public can freely and fairly contribute to the environmental decision process, education on the importance of ecological and genetic diversity is needed. Education will assist the public in assigning both cost and quality of live values to environmental effects as part of the process of assessing the adversity of an effect. Only when the value of an ecological good or service is understood can we determine whether or not to accept the impact or take action to prevent the adverse effect. The decision to prevent or limit adverse effects ultimately leads to regulatory policy.

Benefits from a regulatory action may be underestimated because they are more difficult to measure than the cost of pollution control. Little agreement exists on the time horizon over which costs and benefits should be evaluated or how to balance current costs against the predicted value of future benefits. In a pluralistic society, some of our differing traditions and ethical patterns may conflict. Some individuals and societies may be willing to take risks for immediate, tangible benefits while others would forego current benefits in order to avoid mortgaging the future [24]. Establishing secondary national ambient air quality standards that consider both the long-term and short-term economic and ecological costs and benefits will enable us to work toward an environment that is life sustaining.

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